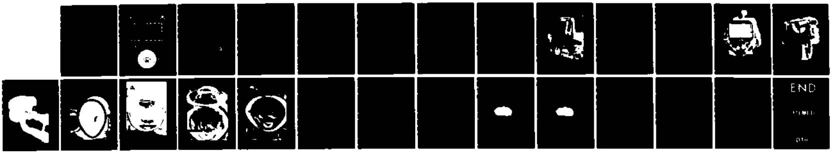
AD-A151 318 HUMAN FACTORS EVALUATION OF THE SAFETY SEA SYSTEMS HELMAX HELMET IN THE OPEN-CIRCUIT MODE(U) NAVY EXPERIMENTAL DIVING UNIT PANAMA CITY FL M D CURLEY 1/1

UNCLASSIFIED SEP 84 NEDU-2-85 F/G 6/17 NL



1.0 4.5 2.8 2.5 5.0 3.2 2.2 5.6 3.6 6.3 2.0 4.0 1.1 1.8 1.25 1.4 1.6

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Navy Experimental Diving Unit

This document has been approved for public release and sale; its distribution is unlimited.

85 03 04 047

DEPARTMENT OF THE NAVY
NAVY EXPERIMENTAL DIVING UNIT
PANAMA CITY, FLORIDA 32407

IN REPLY REFER TO:

NAVY EXPERIMENTAL DIVING UNIT

REPORT NO. 2-85

HUMAN FACTORS EVALUATION OF THE SAFETY SEA SYSTEMS HELMAX HELMET IN THE OPEN-CIRCUIT MODE

By:

Michael D. Curley, LCDR, MSC, USN

September 1984

Prepared by:

MICHAEL D. CURLEY
LCDR, MSC, USN
Research Psychologist

Reviewed by:

J. R. MIDDLETON
GM-13
Senior Projects Officer

E. D. THALMANN
CDR, MC, USN
Senior Medical Officer

Approved by:

FRANK E. EISSING
CDR, USN
Commanding Officer

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NEDU REPORT NO. 2-85	2. GOVT ACCESSION NO. A151318	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) HUMAN FACTORS EVALUATION OF THE SAFETY SEA SYSTEMS HELMAX HELMET IN THE OPEN-CIRCUIT MODE		5. TYPE OF REPORT & PERIOD COVERED FINAL
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) MICHAEL D. CURLEY, LCDR, MSC, USN		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS NAVY EXPERIMENTAL DIVING UNIT PANAMA CITY, FL 32407-5001		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE SEPTEMBER 1984
		13. NUMBER OF PAGES 25
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) HUMAN FACTORS SAFETY SEA SYSTEMS HELMAX HELMET OPEN-CIRCUIT EVALUATION		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A preliminary human factors evaluation of the Safety Sea Systems Helmax multipurpose diving helmet was conducted in the unmanned (dry) and manned (wet) modes. A bench evaluation of the helmet revealed several minor discrepancies revolving around the adaptability of helmet components to varying diver anthropometry. The visual field afforded the diver wearing the Helmax is somewhat restricted but comparable to U.S. Navy MK 12 as assessed by underwater visual perimetry.		

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

However, divers wearing the Helmax during open-circuit test pool dives rated the Helmax adequate or better in the areas of comfort, fit, breathing resistance, communications and ease of operation. No major problems were documented in the area of diver safety while wearing the Helmax helmet during this limited evaluation.

A preliminary human factors evaluation of the Safety Sea Systems Helmax multipurpose diving helmet was conducted in the unmanned (dry) and manned (wet) modes. A bench evaluation of the helmet revealed several minor discrepancies revolving around the adaptability of helmet components to varying diver anthropometry. The visual field afforded the diver wearing the Helmax is somewhat restricted but comparable to U.S. Navy MK 12 as assessed by underwater visual perimetry.

However, divers wearing the Helmax during open-circuit test pool dives rated the Helmax adequate or better in the areas of comfort, fit, breathing resistance, communications and ease of operation. No major problems were documented in the area of diver safety while wearing the Helmax helmet during this limited evaluation.

INTRODUCTION

The purpose of this study was to evaluate the Safety Sea Systems Helmax helmet from a human engineering perspective. Primary considerations in this preliminary evaluation included diver safety, comfort, and ease of operation of the helmet. The helmet was subjected to a dry bench evaluation and formal pool evaluation as outlined in NEDU Test Plan 83-01 (Short Form). Due to time and logistical considerations, the Helmax helmet was evaluated in the surface-supplied open-circuit mode only.

METHOD

SUBJECTS

Seven male U.S. Navy divers and one male Royal Navy diver in good health participated as Diver-Subjects. All men were volunteers with substantial diving experience in many different apparatus. A summary of relevant subject and dive characteristics is presented in Table 1.

EQUIPMENT

Helmax, a multipurpose diving helmet, was furnished by Safety Sea Systems, Inc. (Ponchatoula, Louisiana) for a human factors evaluation. The Helmax helmet tested was Model SS-B, and carried number 62 on the rear as an identifier (Figure 1). Manned wet testing of the Helmax was conducted in NEDU's 208,000 liter indoor pool measuring 4.6m (W) x 9.1m (L) x 4.9m (D). The fresh water in the pool was clear with a temperature ranging between 27 and 29°C. Gas supply to the helmet was via an umbilical from a reducing station. Gas supply was set at 150 psig in accordance with the manufacturer's recommendation, and the breathing gas was compressed air (79% nitrogen, 21% oxygen).

A Collins Pedalmate Ergometer (Warren E. Collins, Inc., Braintree, MA) was placed in a locally constructed tilting frame and adapted for use underwater. Workload was adjusted by means of a Collins Pedalmate Controller on the surface which transmitted an electrical signal to the ergometer via an umbilical cable. Field of vision was measured using a locally constructed perimetry device. This perimeter measured visual angles in 5° increments with radians in 30° increments for the entire 360° viewing field.

A series of 50mm steel rods suspended horizontally in the pool were used by the Diver-Subjects for inversion exercises, and a 1.2m (L) x 25mm (H) x 75mm (W) steel bar was used as a balancing board. Communications with the diver wearing the helmet were via the umbilical and a Helle communication box, using the helmet's microphone and earphones. Operation of helmet valves and components by a gloved hand involved the use of 6mm thick, three-fingered neoprene gloves (Imperial Manufacturing Co., Bremerton, WA). Underwater recording of data was accomplished using pencil and paper ("Kimdura", Munising, Carson, CA). Questionnaires regarding the performance, fit and

TABLE 1. Summary of Subject and Dive Characteristics

Subject	Height (cm;in)	Weight (kg;lb)	Dive Duration (min)	No. of Previous Dives in Helmax
1	183 (72)	86.2 (190)	26	0
2	175 (69)	70.7 (156)	60	0
3	175 (69)	71.2 (157)	59	0
4	175 (69)	74.8 (165)	33	0
5	180 (71)	70.3 (155)	38	1
6	185 (73)	117.9 (260)	20	0
7	178 (70)	79.4 (175)	64	0
8	175 (69)	77.1 (170)	60	1
Mean	178 (70)	80.9 (178.5)	45	--
S.D.	4 (2)	15.9 (35.0)	18	--

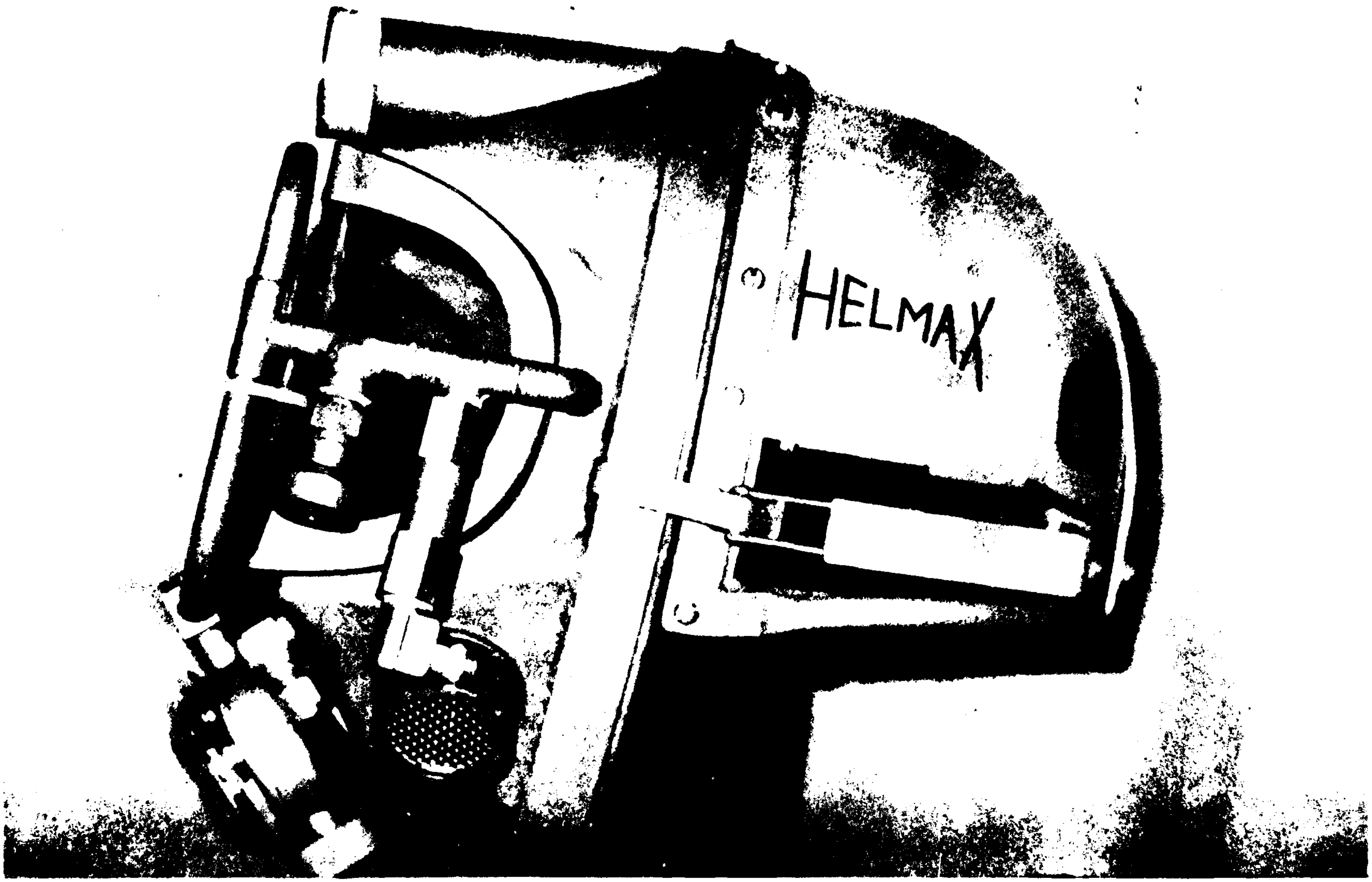


FIGURE 1. Helmax Helmet Number 62; left side view of outer aspect.

comfort of the helmet were completed by all Diver-Subjects after each dive. All subjects wore "shorty" wet suits of neoprene rubber, 3-6mm thick, and weights as necessary to maintain negative buoyancy.

PROCEDURE

An ancilliary human factors evaluation of the Helmax helmet was conducted in a dry, unmanned environment. This bench testing was undertaken to document potential areas of concern regarding design and construction considerations. This bench testing was followed by manned, open-circuit, in-water testing of the Helmax helmet conducted on 24 February and 3 March 1983. A Safety Sea Systems representative, Mr. George Wymer, was on site for the evaluation.

After a briefing on the operation of the helmet and the tasks to be performed in the water, the diver was hatted, given communication and equipment checks, and entered the water. The in-water procedure for each diver followed a similar pattern. After a one to two minute familiarization period, each diver completed a series of 3 roll-overs to his left and right. He then walked on the balance board, hung upside down from a bar suspended in the pool, swam eight laps with fins, walked eight laps, opened and closed the free-flow valve, checked clarity and volume of communications, and applied physical force to assess the integrity of the gas connection at the helmet. The diver then proceeded to the tilting ergometer where he pedalled to maintain a workload of 50 watts for 5 min in a 45° head-up position, 5 min in a 45° head-down position, and 5 min in a prone position. After the ergometer task the diver positioned himself in the visual perimetry apparatus and completed a visual field evaluation.

The diver then donned three-fingered gloves and attempted to operate helmet valves, fittings and fasteners. Upon completion of these tasks the diver surfaced, was debriefed, and completed the questionnaire.

The visual field evaluation was conducted using the "method of limits" with binocular vision. Each Diver-Subject positioned himself by placing the outer aspect of each foot against the piping that defined the base edge of the perimetry device. The experimenter then positioned a yoke brace to stabilize the vertical position of the helmet on the device. Next, a standoff bar with suction cup on the end was positioned in the center of the face plate. In this manner, the standing Diver-Subject's position was stabilized with the helmet centered both horizontally and vertically in the perimetry device. The limit of visual field was then determined. Each Diver-Subject was allowed to keep both eyes open. The visual range was determined by the experimenter slowly moving a white pointer along the outside edge of the 180° arc of the perimetry device. The Diver-Subject indicated when the tip departed from his view by raising a thumb, thus setting the limit of the visual field at a given angle and radian. In this manner, sequential measurements were obtained in radians, in 30° increments, for the entire 360° of viewing field for five divers.

RESULTS AND DISCUSSION

BENCH EVALUATION

The Helmax helmet evaluated was a clamshell opening type constructed of stainless steel and fiberglass. Similar construction techniques and components are used in both the open-circuit and closed-circuit versions. The helmet weighed 11.42 kg on the surface (dry).

The faceplate was constructed of 10mm polycarbonate and measured 16.5cm (L) x 11.8cm (W) x 8cm (D). Gas manifold piping surrounds the front portion of the faceplate (Figure 2) and actually crosses both side portions of the faceplate (Figures 1 and 3), thereby obstructing diver vision out of the side portions. The gas manifold arrangement at the front of the faceplate allows the helmet to be stored resting on the manifold, and affords some protection to the faceplate.

The hood assembly (Figure 4) is placed over the diver's head, forming a seal around the neck (neck dam) and around the face. The face cut-out (Figure 5) can be formed to fit individual divers. The hood assembly should be available in several sizes to ensure proper fit around the neck, head and face. An extended shoulder flap (bib) would also result in a more comfortable fit and seal than the present configuration.

The color of the fiberglass helmet shell is yellow for high visibility. The locking levers (Figure 3) require a solid, positive action by the diver to shut and open, and provide adequate feedback as to the position of the levers. An additional safety device to prevent accidental opening of the levers underwater is recommended. An adjustable head/skull cap (Figure 6) is suspended from the rear of the helmet, and can be easily snugged up via velcro tabs by the diver for comfort.

The diver breathes through an oral-nasal mask (size medium), made of silicone and designed for oxygen pressure breathing. The outer sides of the oral-nasal are fastened to the face cushion by velcro tabs. While many divers will find a "medium" mask provides an adequate seal, others of varying anthropometric characteristics will require smaller or larger masks for use. A nose clearing (equalization) device (Figure 7) is provided to assist the diver in equalizing pressure. This device rotates and moves in and out. A rubber pad covers the curved metal device. As evaluated, the metal was pre-formed, unable to be shaped by diver finger pressure, and not contoured to many of the divers' noses, thus rendering the device ineffective. This thoughtful addition to the helmet would be greatly improved by using a material which can be bent to the comfort of the diver.

Two small speakers (5.1cm outside diameter) rest in the face cushion (Figure 8) which in turn rests against the diver's neck dam assembly, separated by 0.4cm neoprene rubber. The placement of these speakers at the forehead level vice over the ears should be acceptable provided there is no pressure exerted by the speakers towards the forehead.

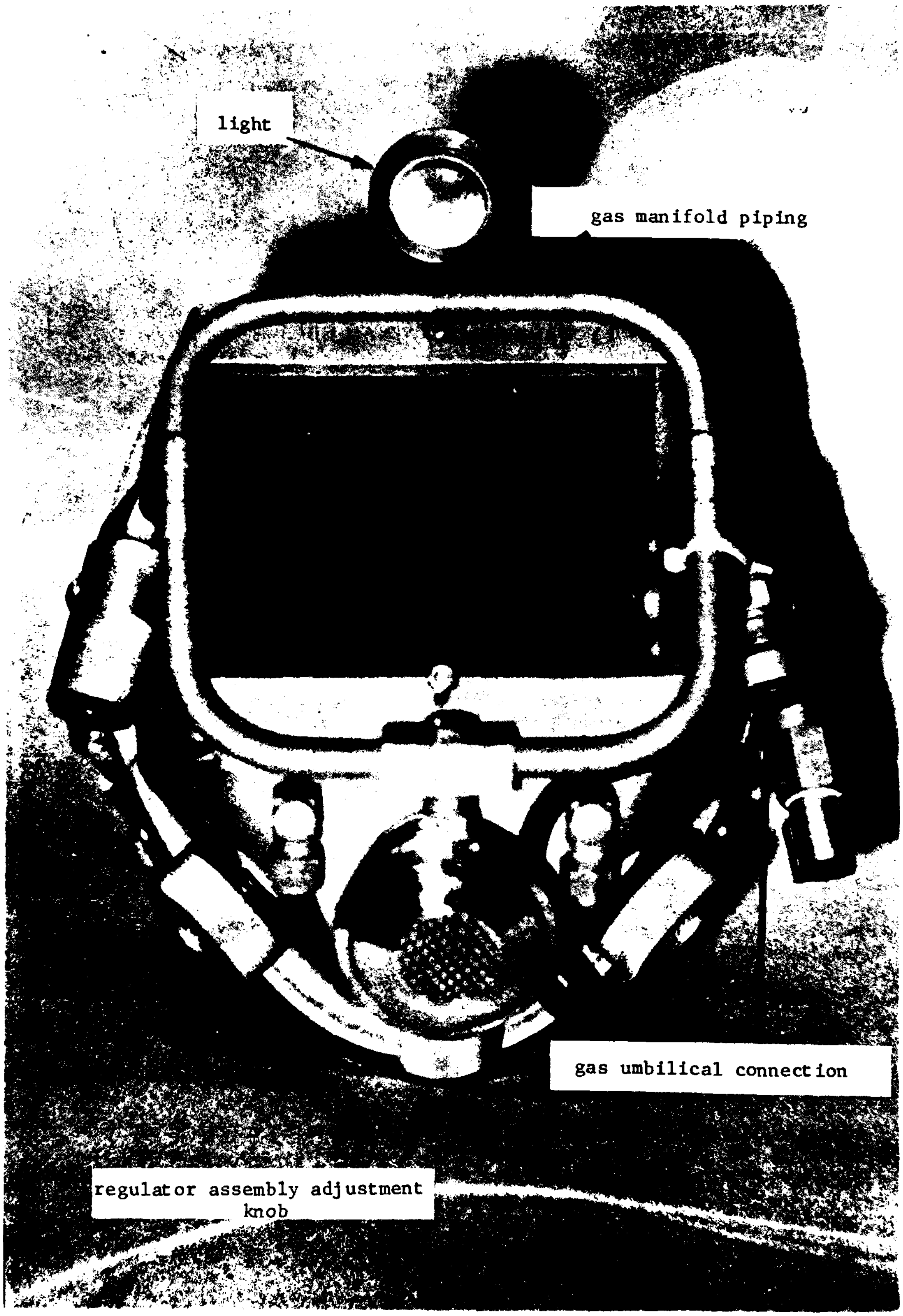


FIGURE 2. Helmax helmet; front view of outer aspect.

FIGURE 3. Helmax Helmet; right side view of outer aspect.

FIGURE 4. Hood assembly with integral neck-dam.

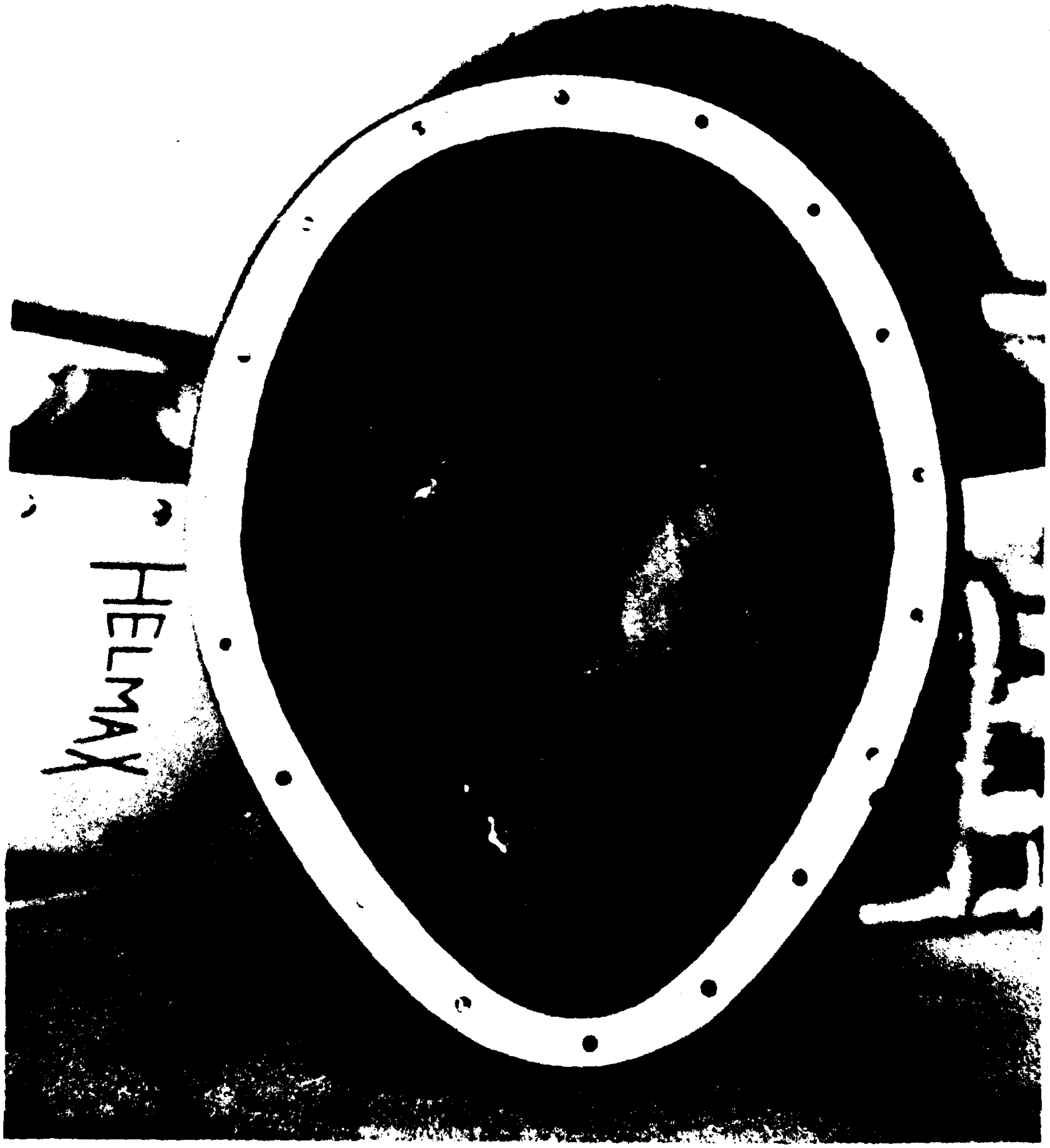


FIGURE 5. Hood assembly with face cut-out.

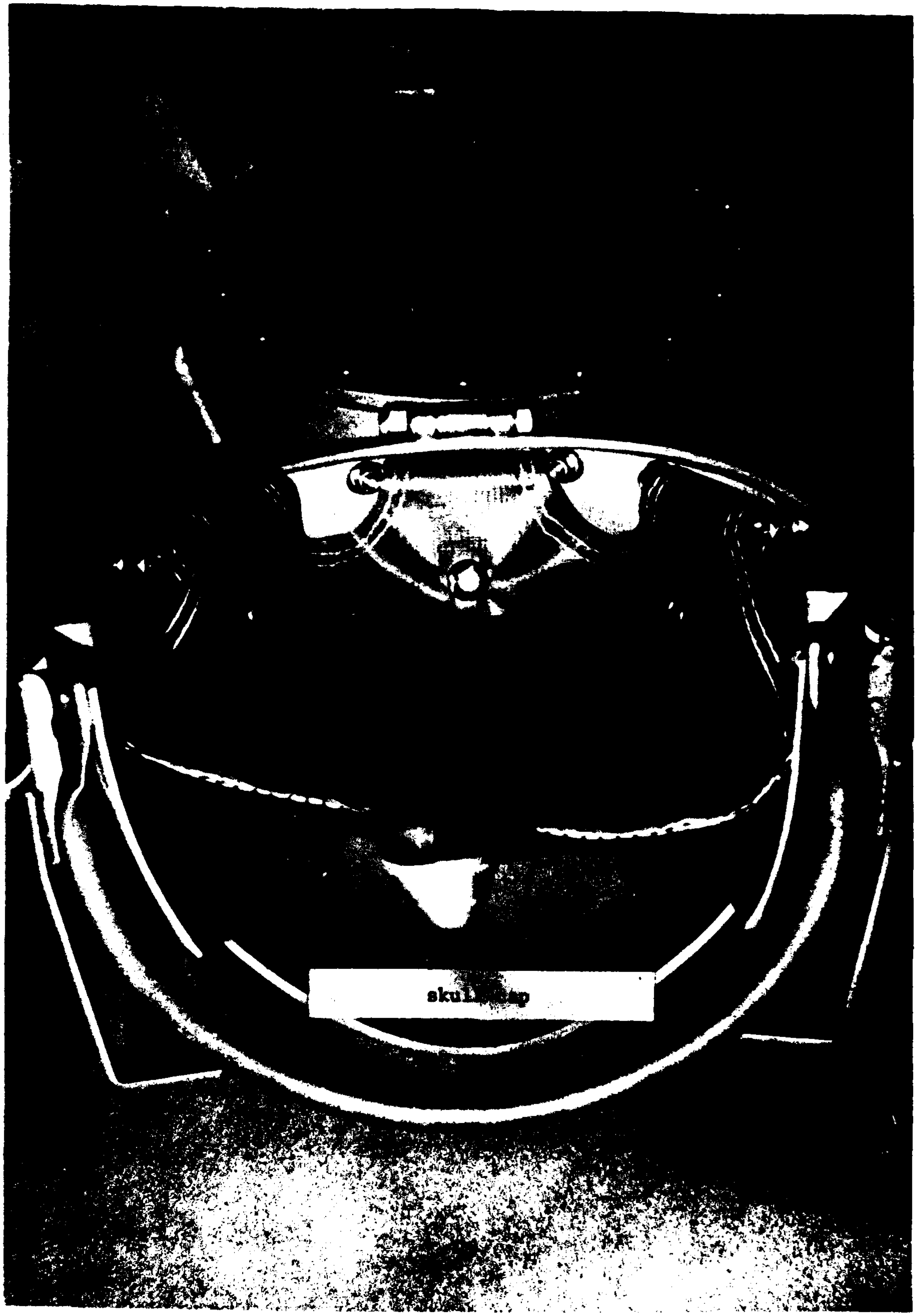


FIGURE 6. Adjustable head/skull cap suspended from rear of helmet.

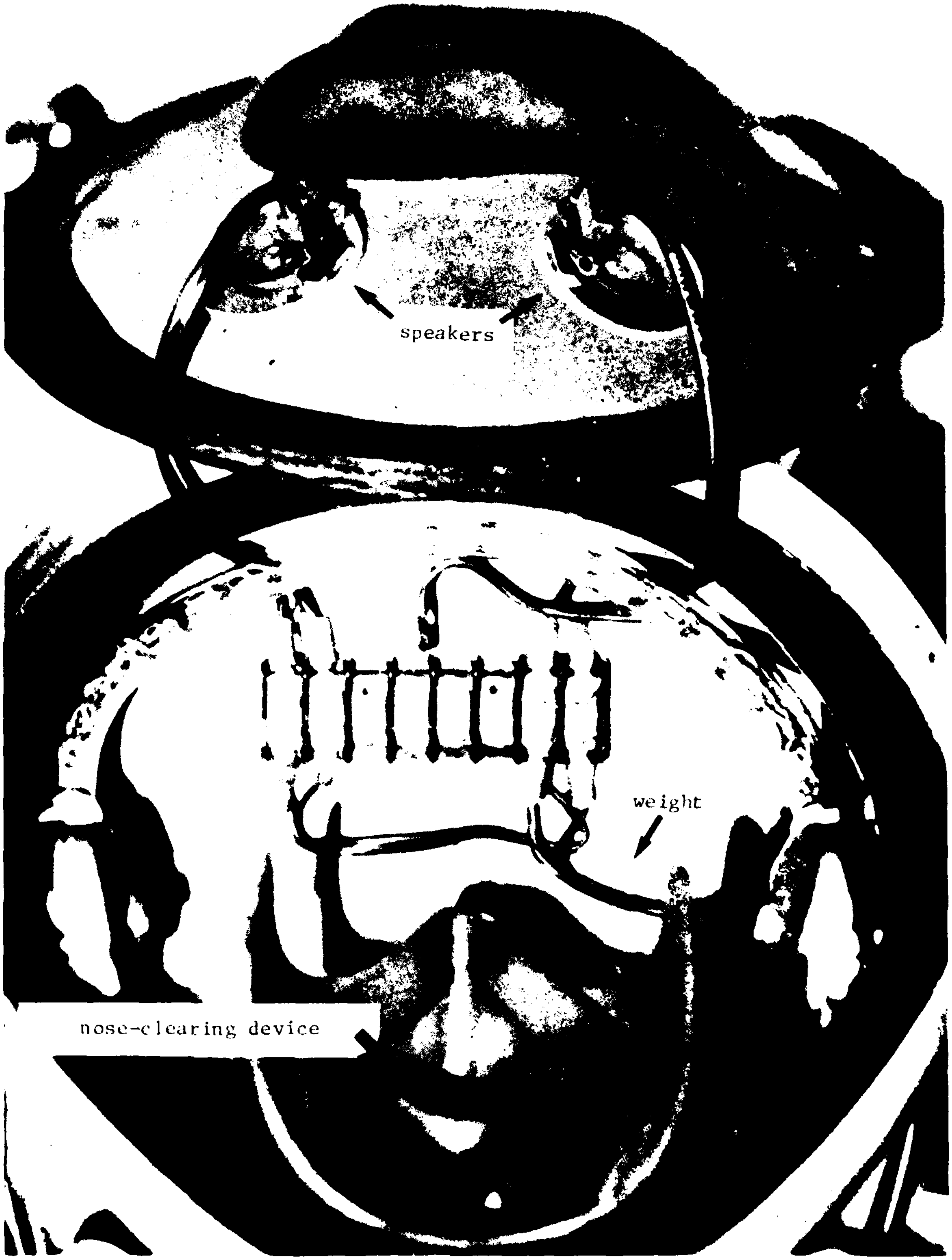


FIGURE 7. Inner aspect of front of helmet showing nose-clearing device; oral-nasal mask, and communications.

FIGURE 8. Front asp[illegible] [illegible] showing placement of communication speakers [illegible] mask.

A free-flow valve was located on the right side of the helmet (Figure 3). It measured 3cm outside diameter and was 6cm long. The lower 3.2cm of the valve was knurled (8 knurls/cm) for ease of grasping with a bare or gloved hand. The free-flow valve had a quarter turn range from full "on" to full "off", which provided for positive control by the diver and easy operation. The free-flow valve is in the right visual field of the diver, and obstructs vision in that field. Two exhaust ports are located below the oral-nasal exhaust ports (Figure 2) and have an inside diameter of approximately 4cm. These ports are removable simply by grasping the knurled ports and unscrewing.

There is a communications entry below the oral-nasal mask. Two bolts face towards the oral-nasal mask and lower left jaw of the diver. These bolts can be felt by the diver and present a potential hazard. A removable protective cap (e.g. of hard rubber) would minimize the hazard. The regulator assembly contains an adjustment knob (Figure 2) for compensating for different supply pressures. This adjustment requires 8 1/2 turns from full open to full close. The knob is 1.4cm high, has a 3cm outside diameter, and has 8 knurls/cm. It was easily grasped and operated by divers with 3-fingered neoprene gloves.

VISUAL FIELD (PERIMETRY)

The results of the visual field evaluation completed on five divers in the test pool are presented in Table 2. Compared to normal unrestricted binocular vision, diver vision in the Helmax is most restricted in the lower left and lower right quadrants. A graphic example of this is presented in Figure 9, where the solid line represents the normal unobstructed binocular vision and the dotted line represents average peripheral vision obtained from the Helmax-hatted divers. The areas of greatest visual decrement from normal binocular vision occur from 195° to 240° and from 300° to 345°.

Further comparisons of visual fields are presented in Figures 10 and 11. The field of vision obtained from a U.S. Navy Mark 11 helmet (1) is shown in Figure 10, along with the Helmax diver's visual field. The Helmax visual field is represented as the shaded area; the Mark 11 visual field as the dashed line. Figure 11 presents the field of view of divers in a prototype U.S. Navy Mark 12 helmet <u>without</u> sideports [(2), dashed line] in comparison to the Helmax (shaded area).

DIVER RATINGS

Following his dive each Diver-Subject completed the questionnaire. Thirteen questions required a numerical rating and comment from the subjects; two questions required YES-NO answers and comment, and five questions called for written comment alone. Mean ratings, standard deviations, and number of responses to each question are presented in Table 3.

As seen in Table 3, the Helmax helmet was given its highest ratings in the area of communications ($\bar{X}$ = 5.6, "very good" -"excellent"). Diver comments

TABLE 2. Results of visual field evaluation completed on five divers wearing the Helmax.

RADIANS

	0		30		60		90		120		150		180		210		240		270		300		330	
SUBJECT NO.	in	out	in	out	in	out	in	out	in	out	in	out	in	out	in	out	in	out	in	out	in	out	in	out
8	50	60	50	60	30	30	35	35	35	35	65	60	65	70	70	75	45	45	35	35	35	40	65	75
2	65	65	30	30	25	30	40	40	25	20	30	30	80	85	75	75	20	20	35	35	40	40	70	75
7	55	45	50	50	25	25	40	40	20	20	50	30	60	60	65	65	35	30	20	15	45	45	50	35
3	70	65	35	30	25	25	20	20	25	25	65	65	65	65	35	35	35	35	30	35	30	40	70	70
5	50	35	30	30	20	20	25	25	25	25	30	35	45	55	35	35	30	35	20	20	35	35	40	50
$\overline{X}$ =	58	54	39	40	25	26	32	32	25	25	48	44	63	67	56	57	33	33	28	28	37	40	59	61
$\frac{\overline{X}_i + \overline{X}_o}{2}$ =	56		39.5		25.5		32		25.5		46		65		56.5		33		28		38.5		60	

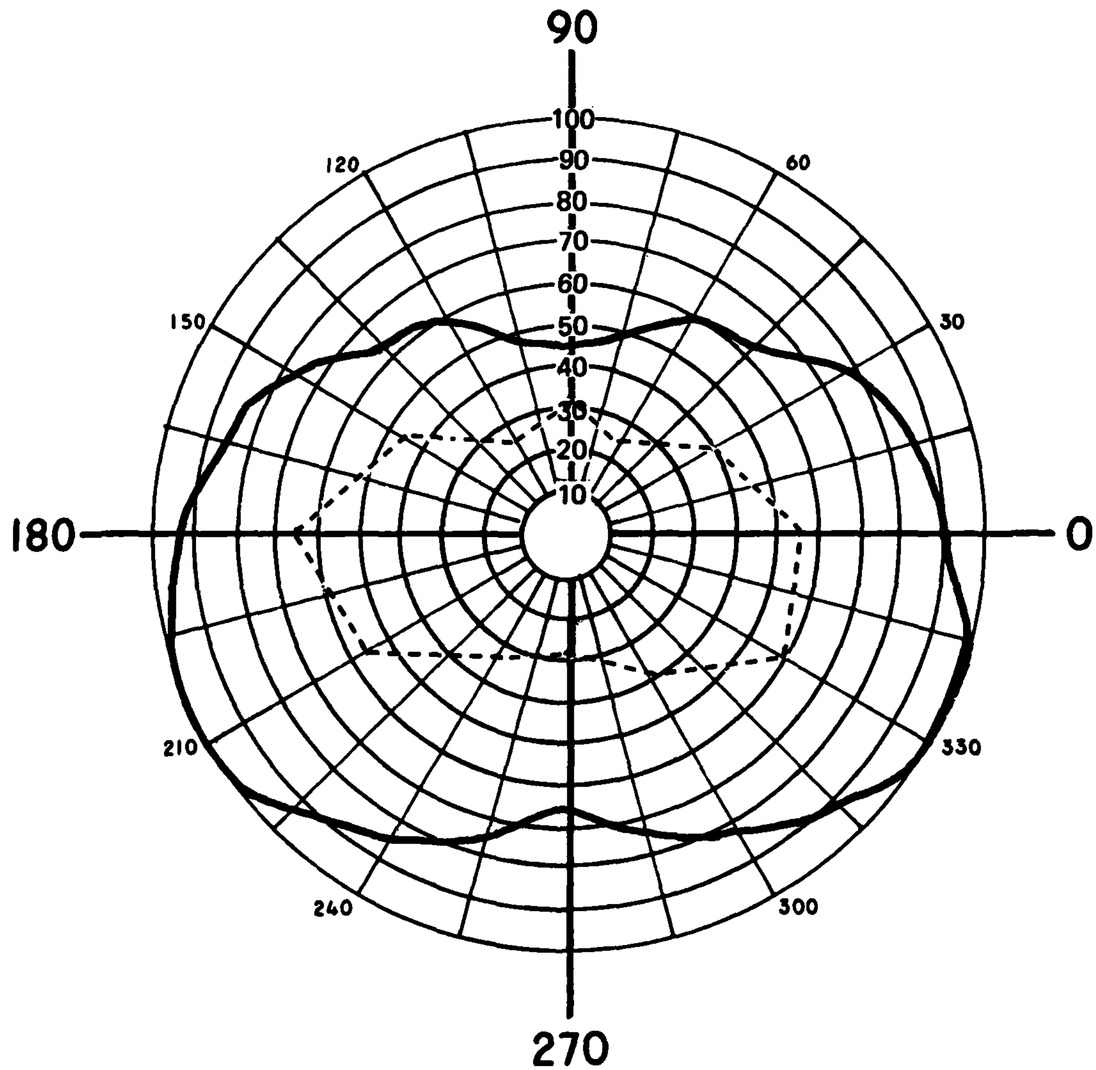


FIGURE 9. Comparison of the visual field of divers in the Helmax helmet (dashed line) with normal unobstructed binocular vision (solid line).

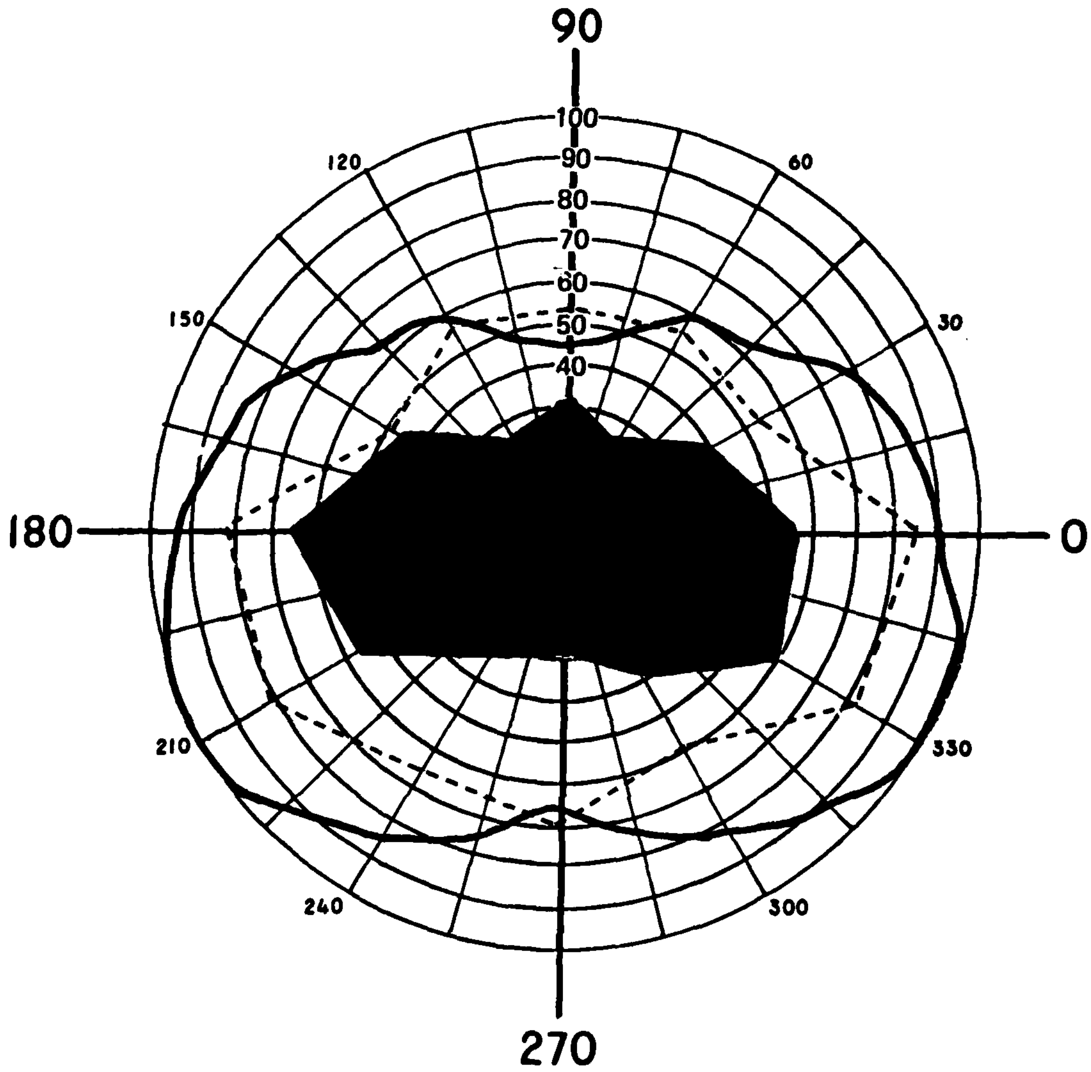


FIGURE 10. Comparison of the field of vision of divers in a U.S. Navy Mark 11 helmet (dashed line), divers in the Helmax helmet (shaded area), and normal unobstructed binocular vision (solid line).

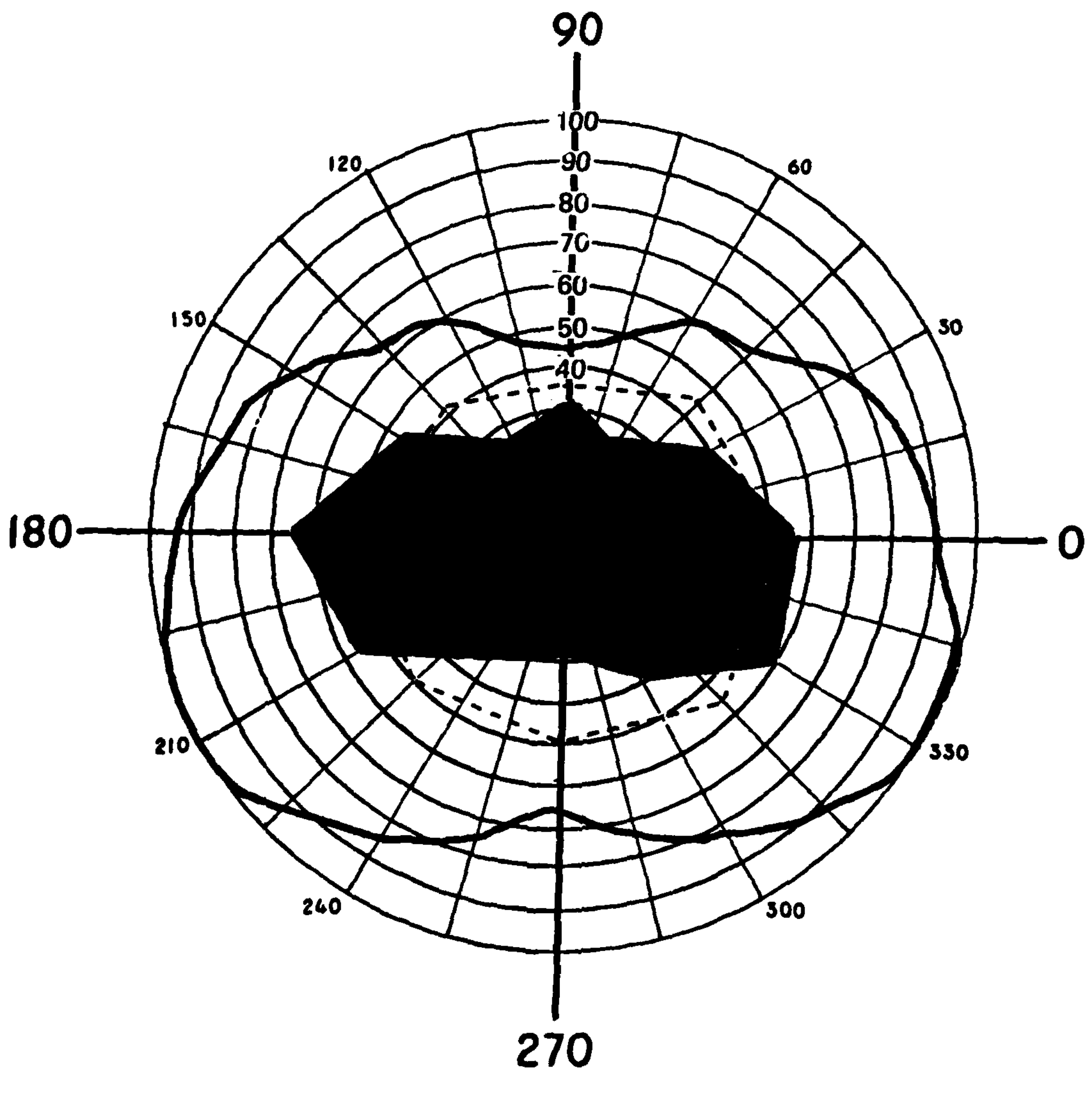


FIGURE 11. Comparison of the field of vision of divers in a prototype U.S. Navy Mark 12 helmet without sideports (dashed line), divers in the Helmax helmet (shaded area), and normal unobstructed binocular vision (solid line).

centered on the diver's ability to clearly hear topside communication even when the helmet's free-flow valve was completely opened, and that communications in the Helmax were judged superior to other rigs. The lowest rating assigned the Helmax was in the area of topside freedom of movement and helmet visibility ($\bar{X}$ = 3.6, "not quite adequate" -"adequate"). Several divers reflected that the Helmax was front heavy on the surface, but this distribution of weight was not a major concern. Breathing resistance of the Helmax in all four body positions was rated "minimal" to "tolerable" by the Diver-Subjects. Two divers who experienced difficulty in swimming with the Helmax focused their criticism on (1) the weight distribution of the helmet which tended to place the diver in a head-down attitude when swimming horizontally, and (2) the limited upward visibility afforded the diver in the Helmax helmet.

With the exceptions previously noted, diver mean responses to the questions rated the Helmax as "adequate" or "very good" in the areas queried. Suggestions from the divers for areas of possible helmet improvement included removal of piping from around the faceplates (for better visibility), extending the front faceplate upward for improved visibility, and moving the ports closer to the diver's eyes. Comments regarding the most uncomfortable aspects of the Helmax included the nose clearing device, the skull cap mating ring, the helmet being front heavy on surface, and one comment indicating that if secured too tight, the helmet can cause a headache in the forehead. The parts of the Helmax the divers thought appeared to lack durability if subjected to Fleet use were the neck dam and oral-nasal mask. Several positive comments were made regarding the ease of doffing and donning the helmet with the large locking levers.

CONCLUSIONS

This preliminary human factors evaluation of the Helmax helmet (open-circuit mode) revealed no major problems in regard to the areas of diver comfort, safety, and operation. The most noticeable area of concern is the diver's limited visibility when encapsulated in the Helmax, a concern noted by several divers and verified by the visual perimetry study. The diver's visual field is restricted by the piping on each sideport. A lowering of the side gas piping approximately 50 mm from its current positioning would rectify the visual problem; however, this would also remove the free-flow valve and gas umbilical connection from the diver's field of view, resulting in a less than desirable solution.

During the evaluation, several problem areas were noted, all of which appear to be amenable to modification for improved diver safety, comfort, and ease of helmet operation. These areas included the: (1) nose-clearing device, (2) weight distribution of the helmet, (3) availability of different sizes of the hood assembly, (4) absence of a safety catch on the locking levers, (5) availability of varying sizes of the oral-nasal mask, and (6) absence of a protector for the communication bolt posts. In the important areas of comfort, fit, breathing resistance in various positions, communications, and ease of operation, the Helmax helmet was judged adequate or better by the divers.

TABLE 3. Summary of ratings assigned to the Helmax helmet on several characteristics by Diver-Subjects in response to questions on post-dive survey.

KEY: 1. extremely poor 2. poor 3. not quite adequate 4. adequate 5. very good 6. excellent

Question		Number of Responses	Rating [Mean, (S.D.)]
How do you rate the ease with which you were able to don the helmet you have just worn?		7	4.7 (0.5)
How do you rate the fasteners, fittings and valves provided on the helmet?		8	4.6 (1.0)
How do you rate the fit of:	skull cap?	6	4.3 (1.2)
	oral-nasal?	7	4.9 (1.1)
	helmet?	7	4.4 (1.0)
How do you rate the comfort of:	skull cap?	7	4.6 (1.3)
	oral-nasal?	8	5.1 (1.0)
	helmet?	8	4.1 (1.4)
How would you rate helmet visibility?		8	3.6 (1.2)
How do you rate the helmet you tested for freedom of moving about the topside area or topside work before entering the water?		8	3.6 (1.2)
How do you rate the locations of the emergency valve in the rig you have worn?		8	4.8 (0.9)
How do you rate the ease of operation of the valves on the helmet you have worn?		8	4.7 (1.1)
How would you rate the thermal protection of the helmet you tested?		5	5.0 (0.7)
How would you rate the communication system of the helmet?		5	5.6 (0.6)

TABLE 3. (Continued)

KEY: 1. Heavy
2. Moderate
3. Tolerable
4. Minimal

Question	Number of Responses	Rating [Mean, (S.D.)]
How would you rate the breathing resistance of the rig in the -upright position?	8	3.8 (0.7)
-45° head-up position?	8	3.8 (0.7)
-prone position?	8	3.6 (0.7)
-45° head-down position?	8	3.4 (0.7)

Did you have any difficulty swimming? YES 2 NO 6

Did you feel the neck dam was adequate? YES 7 NO 1

END

FILMED

4-85

DTIC